Human Fall Detection Using Standard Deviation of C-Motion Method

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***Abstract*—Nowadays, the number of elderly people is continuously increasing, therefore fall detection system is becoming more important to elder who left alone because the fall may cause injury or even mortality. This paper proposes the fall detection system using IP Camera that installed on high position like bird's eye view for getting wide angle view of the room. This system detects human fall on real time basis using "Standard Deviation of C-Motion" method which indicating the changing rate of human motion, and using "The Orientation Standard Deviation of The Ellipse" method which indicating the changing rate of human shape. Last step, we use three essential conditions for verify the "Fall" motion. The experimental results show that the proposed fall detection system can be used in practical.**

***Index Terms*—Image processing, fall detection, Motion History Image**

I. Introduction

Elder people age around 65 and above mainly subject to injury or even mortality after their falls. Therefore, fall detection systems were developed utilizing Close Circuit Television (CCTV) as a main detector. CCTVs are installed in various locations within elderly residence. When fall is detected, fall detection system will send warning signal to specific location such as hospital or police station.

Previous fall detection systems were researched and developed as described in following detail. In early phase, multi-cameras were installed in high-risk areas [1]. However this method is expensive and not cost effective. Later on, 3D tracking head with a single camera was developed [2]. This technique analyzes the velocity of head in horizontal and vertical axis. Even though the cost is lower but the calculation is too complicated. Thus, it cannot generate warning signal within the time limit. Next development is the estimation of fall using approximate bounding box [3]. This method analyzes the changing of bounding box and then performs "Feature Extraction" calculation such as, aspect ratio of bounding box, inclination angle [4], changing rate in human centroid and vertical projection histogram value[5]. However, visual obstruction which caused by house furniture or objects may cause problems to the detection system due toplacing the camera on side view. Next, the "C-Motion" method, this method is a measurement of human motion by computing from Motion History Image (MHI) method, which indicates speed of human motion [6]. If subject conducts unusual activities such as taking a fast walk or run, C-Motion method will return a high value computation result because this method considers velocity of motions.

This article presents the use of "Standard Deviation of C-Motion". This method will compute acceleration value of human's movement for indicating the changing rate of human motions. In our assumption, human fall is high acceleration activity, whereas fast walking and running are considered as low acceleration activities. Thus standard deviation of C-Motion method together with the orientation standard deviation of the ellipse is able to discriminate actual fall from other activities.

II. System Overview

The human fall detection system on this paper consists of an IP camera which is connected to a PC for computing and detecting falls inside home by considering daily activities such as sit, bend, lie and unusual activities such as run and fall.

Firstly, the detection system will analyze the movement of human. Therefore, the foreground segmentation method is employed for indicating human's location on the image. After that Motion History Image method is applied. This method provides information of movement. Next, the C-Motion method is calculated from Motion History Image. The calculated C-Motion value will describe the speed of movement. Later, the standard deviation of C-Motion value is calculated. This method provides the information about the changing rate of human motion. If this standard deviation value has high changing rate, it indicates that there is unusual activity. After that, the approximated ellipse method is employed to fit to the human foreground for analyzing the changing of the shape of ellipse.

Next, the orientation standard deviation of the ellipse is calculated from the shape of ellipse. This calculation provides information about the changing rate of human shape.

If this value has high changing rate, it shows that fall may arise, which verify after the fall arise by our defined conditions. These conditions described in section IV.

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If the calculated standard deviation value is high, then it indicates that fall may arise.

Then, the human motion after this is rechecked again to check that the human body has no movement. This is to ensure that it is the actual fall. These three essential conditions for checking the actual fall will be described is section IV.

III. Method Details

A. Foreground Segmentation

Foreground segmentation is a method of object movement detection which separate foreground from background. We uses Adaptive Gaussian Mixture Model algorithm which adjusts the intensity value according to changing of background [7].

B. Motion History Image

This algorithm tells about quantity of motion and direction of movement. In Motion History Image, we derive binary image of motion, $D(x,y,t)$ from original sequence of images by image differencing method.

Each pixels of Motion History Image, H_τ is intensity function of historical period at one point of time that occur during period τ as in (1).

$$H_\tau(x,y,t)=\begin{cases}\tau & ;\text{if } D(x\ y\ t)= \\ \max(0,H_\tau(x,y,t-1)-1) & ;\text{otherwise}\end{cases} \quad (1)$$

The resultfrom (1) is scalar image which the recent motion will have brightest pixels. While, the historical motion will have decreasing brightness as time pass by. This method provides information about motion quantification in normal activities which have low movement, and in unusual activities which have high movement as illustratedin Fig. 1.

(a) walk (b) bend (c) fall

Figure 1. Examples ofMotion History Image; (a) for walk, (b) bend and (c) fall.

C. Motion Quantification

This method is the measurement of human motion by calculating pixel value ofMotion History Image blob in present divided by number of pixels in human blob. The calculation is shownin (2) below.

$$C_{motion}=\frac{\sum Pixel(x,y)\in blob\, H_\tau(x,y,t)}{\#\, pixel\in blob} \quad (2)$$

Value of C_{motion} is the percentage between 0%(no movement) and 100% (high movement). We calculate Motion History Image by accumulate the movement during 0.6second.

After that we find standard deviation of C-Motion, $\sigma_{C_{motion}}$ as displayed in (3).

$$\sigma_{C_{motion}}=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(C_{motion_i}-\bar{C}_{motion})^2} \quad (3)$$

C_{motion_i} is the motion quantification which is calculated from the i–th frame. $\bar{C}_{motion}$ is the average value within the specified a number of frames. N is number of frame within specified slide time frame. In this research, the period of slide time frame is 1 second and number of frame per one slide time frame is20 frames.

$\sigma_{C_{motion}}$ indicates changing rate of human motion, and it isused to discriminate unusual activities from normal activities. In fall motion, both value of C_{motion} and $\sigma_{C_{motion}}$ will have high value. While, theother unusual activitiessuch as fast walk and run, the value of C_{motion} will have high value but value of $\sigma_{C_{motion}}$ will have low changing rate.

D. Approximated Ellipse

We use "Approximated Ellipse" method for analyze the changing of theshape of ellipseon all human activities.

Ellipse is defined by the center of ellipse $(\bar{x},\bar{y})$, its orientation,the length of major and minor semi-axes represented by "a" and "b" accordingly.

From the continuous image value $f(x,y)$, the movement is given by(4).

$$m_{pq}=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x^p y^q f(x,y)\,dxdy \quad ; p,q=0,1,2. \quad (4)$$

The center of the ellipse can be computed from the first-order and the zero-order moments: $\bar{x}=m_{10}/m_{00}$, $\bar{y}=m_{01}/m_{00}$.

The coordinate of center $(\bar{x},\bar{y})$ is used to calculated central moment as in (5).

$$\mu_{pq}=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}(x-\bar{x})^p(y-\bar{y})^q f(x,y)\,dxdy \quad (5)$$

Equation (6) is employed to fine the angle (θ) between major axis (a) of ellipse and horizontal axis of image, which can be calculated from the second order equation of central moment.

$$\theta=\frac{1}{2}arctan(\frac{2\mu_{11}}{\mu_{20}\mu_{02}}) \quad (6)$$

After we derive the orientation ellipse feature, then calculate the orientation standard deviation of the ellipse, σ_θ as shown in (7).

$$\sigma_\theta=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(\theta_i-\bar{\theta})^2} \quad (7)$$

Where θ_i is the orientation of ellipse which is calculated from the *i–th* frame. $\bar{\theta}$ is the average value of θ within the specified number of frames. *N* is number of frames within specified sliding window. In this research, the period of slidingwindow is 1 second and number of frames per onewindow is 20 frames.

The examples of fitted ellipse in normal activities (walk, bend, and sit) are illustrated in Fig. 2 and Fig. 3 shows the examples of fitted ellipse in unusual activities (run, fall).

Figure 2. Normal activities

Figure 3. Unusual activities.

IV. Fall Recognition

We use standard deviation of C-Motion, $\sigma_{C_{motion}}$, and the orientation standard deviation of the ellipse, σ_θ, method for distinguish fall from other activities by setting three essential conditions as follow:

- Condition 1: Ifvalue of $\sigma_{C_{motion}}$ is higher than threshold value, then the value of σ_θ during1 second before will be used to analysis.
- Condition 2: If the value of σ_θ is higher than threshold value then fall may occur.
- Condition 3:The last step is to verify after the fall arise. If no motion is detected during 5 second, under the given rules $\sigma_{C_{motion}} < 5$ or $\sigma_\theta < 5$. However, if motion is still detected during 5 second after fall, then fall does not arise.

In this research, the threshold value for $\sigma_{C_{motion}}$ is 18, and the threshold value for σ_θ is 20.

The "Fall" motion is confirmed when it meets all three mentioned conditions. Fig. 4 is an example of "Fall" motion. The red line represents σ_θ, green line represents $\sigma_{C_{motion}}$, red dashed line represents threshold value for σ_θ and green dashed line represents threshold value for $\sigma_{C_{motion}}$.

On the displayed figure, the value of $\sigma_{C_{motion}}$ is higher than threshold value. This condition meets condition 1($\sigma_{C_{motion}}$ > threshold value).

Next, the analysis of σ_θ value during 1 second before which value of σ_θ is higher than threshold value. This condition meets condition 2(σ_θ > threshold value).

Then, themotion 5second after fall may arise is analyzed to ensure that there is no movement.This condition meets condition 3($\sigma_{C_{motion}}$ <5 or σ_θ <10).

When all of these 3 conditions are met, then we can ensure that the fall occurs.

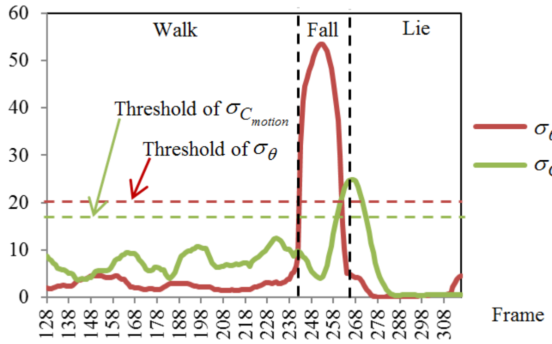

Figure 4. Example of fall.

V. Experimental Result

Our system is designed by usinglow cost IP camera with resolution 320×192 pixels and frame rate 20 frames per second. The camera is installed at bird's eye view position for getting a wide angleview, about 70 degrees. This fall detection system is computed by using OpenCV Library of C++.

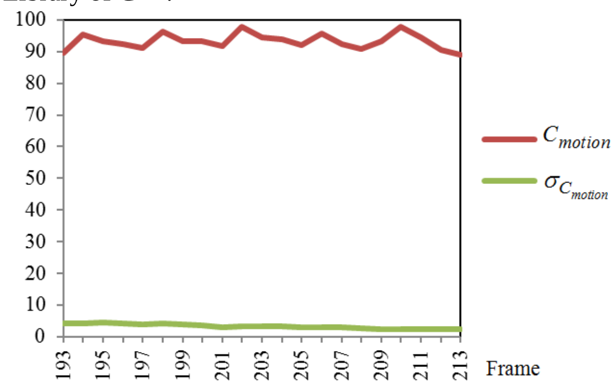

Figure 5. Example of run

Fig. 5 is example of "Run" motion. The red line shows the value of C_{motion} and green line represents $\sigma_{C_{motion}}$ .The value of C_{motion} is very high, whereas the value of $\sigma_{C_{motion}}$ is low. This condition does not meet condition 1($\sigma_{C_{motion}}$ > threshold value).

Fig. 4 is example of "Fall" motion. Value of $\sigma_{C_{motion}}$ is higher than threshold value (Condition 1). This leads to the analysis of σ_θ value during 1 second before. Fromthe chart in Fig. 4, value of σ_θ is also higher than threshold (Condition 2) which indicates that the fall may arise. Then, the motion 5 seconds after fall may arise is analyzed to ensure that there is no movement after the fall

(Condition 3).This example meets all of these 3 conditions,thus fall occurs.

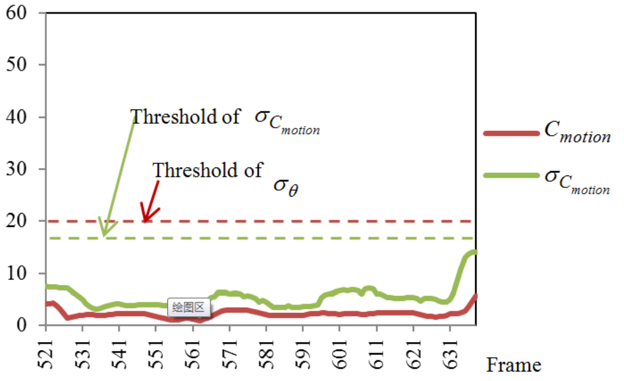

Figure 6. Example of walk.

Fig. 6 is example of "Walk" motion. The value of $\sigma_{C_{motion}}$ is less than threshold value, thus no fall occurs.

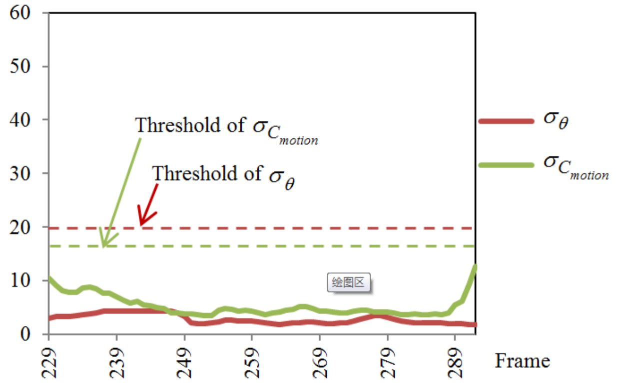

Figure 7. Example of fast walk.

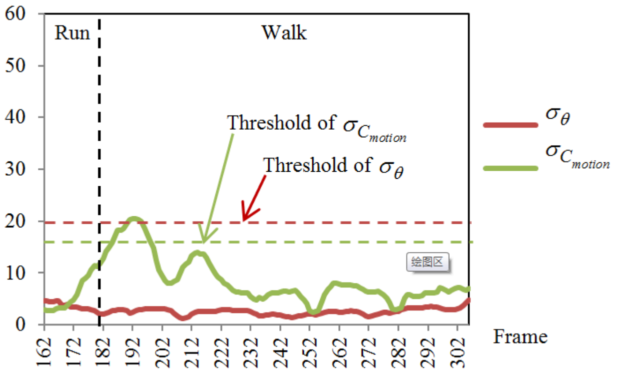

Figure 8. Example of run to walk.

Fig. 7 is example of "Fast Walk" motion. The value of $\sigma_{C_{motion}}$ is less than threshold value, thus no fall occurs.

Fig. 8 is example of "Run" changing to "Walk" motion. The value of $\sigma_{C_{motion}}$ is higher than threshold value (Condition 1 is met). However, the value of σ_θ during 1 second before is lower than threshold value (does not meet Condition 2), thus no fall occurs. The $\sigma_{C_{motion}}$ value exceeds threshold value due to high change rate of human motion caused by immediate change of action from run to walk.

VI. Conclusion and Discussion

This research is the presentation of new method of fall detection which can discriminate fall fromother activities by using standard deviation of C-Motion, $\sigma_{C_{motion}}$, and the orientation standard deviation of the ellipse method, σ_θ, and also use three essential conditions for the "Fall" motiondetecting. These methods are important to discriminate the fall from other daily activities. This fall detection system is robust which make this system highly practical.

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